

During the trial the bulging in and bulging out of the extended and compressed sides of Fig. 2 were plainly visible; but no such distortion of Fig. 1 was to be detected, although its diameter was repeatedly tried with callipers.

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ART. VI.—*Notes on the Coast Line Formation of the Western District, and Proofs of the Uniform Condition of Meteorological Phenomena over long periods of time.*

BY MR. T. E. RAWLINSON, C.E., &C.

[Read on the 14th June, 1877.]

Two years ago a very interesting paper, by Mr. R. Etheridge, on the sand dunes of the coast of Victoria, was read before this Society; and I purpose following up the subject by a few notes of personal observations on the same subject, connecting it with volcanic phenomena of the locality.

My observations are chiefly confined to the portion of coast line from a few miles east of Warrnambool to a few miles west of Belfast.

My object in doing so this evening is to bring forward evidence which I consider conclusive in reference to establishing the fact of the permanence in this locality over great periods of time of climatic conditions, and the several changes in the coast line during the same period.

The present coast line from the River Hopkins, east of Warrnambool, to the Yambuk Lake entrance, about ten miles west of Belfast, is the third and last line of beach, and consists chiefly of pulverised shells; and, as Mr. Etheridge points out, echini spines and other marine remains, to which I may add enormous quantities of calcareous operculums, which, from their great strength, have borne with impunity the bruising which has mostly destroyed the parent univalves, although in places there are many of these univalves yet left on the dunes, together with the helios limpet and more ordinary bivalves of the present sea.

In all cases where I have tested the so-called sand with acids, 80 per cent. and upwards has dissolved, leaving a small residuum of reddish mud or clay, and the remainder particles of silica (or sand).

From Belfast, for a distance of from four to five miles easterly, I have often found pure flint nodules, with the outward white coating precisely the same in appearance as those obtained out of the chalk hills of Kent; and if it were not for the number picked up from time to time at various places on the line of hummocks, I should have been disposed to think their occurrence purely accidental, the more especially as I know of no other place where they occur near to Belfast, nor do I know nor can I conjecture the agency at work in their formation.

Between two and five miles east of Belfast I have been much surprised to find the frequent recurrence of human remains (nearly always in pairs), which had become bared and the bones mingled together, owing to the action of the wind on the drifting sand. I have counted as many as 50 undoubted remains, without taking into account scattered bones which may have belonged to other groups; but in only one case have I seen a perfect skeleton, and this was just above high-water mark, the sand around it being tinged a darker shade, the skull being a little distance away, and perfect. Owing to matters of business preventing my attending to the affair at that time, I lost the opportunity presented of securing the skeleton, owing to the wind and other causes having disturbed the remains. That all the remains were human cannot be doubted, because of the presence of the leg, thigh, and arm bones, the ribs and vertebræ, and frequently the skulls, with the front teeth of the upper jaw wanting.

From frequent enquiries made of the oldest residents in reference to the remains, I could obtain no information; and natives who used to muster in Belfast under the genial hospitality of their protector, Mr. Dawson, when first questioned on the subject evidently knew nothing of it; but after they had time to consider the object of the questioning, they, with the well-known courtesy of the race, had a reply which they evidently considered was the answer wanted.

Some years afterwards, in conversation with Mr. Goodall, the Superintendent of the Framlingham Aboriginal Station, he informed me that he had no doubt he could obtain what information there was to be had from an old Port Fairy blackfellow on the station; but on my expressing doubt as to the value of such evidence, he replied that from long acquaintance with them he felt sure he could question them

and obtain truthful replies to his answers, unmodified by qualifications and inventions given with a view to please.

Shortly afterwards Mr. Goodall informed me that the old blackfellow said there had been a great shooting; that "Blackfellow had been rounded up and shot by whitefellow." Mr. Goodall expressed himself as perfectly satisfied that the answer was given in good faith, and was true; and this will account for the singular occurrence of the remains in couples, which so frequently, and as far as my observations went, always occurred, the perfect skeleton on the beach excepted.

The above being true (and I think it very probable), it is but a confirmation of those accounts so frequent in connection with the early settlement of the country, of the wretched natives in their ignorance interfering with the white man's flocks and herds, and provoking these terrible reprisals. It constitutes murder of the same class with that of a Queen's ship, armed with the most perfect weapons and skilled men, shelling a native village in Polynesia, and destroying wholesale, in revenge for some isolated outrage by one or two of the natives, who in all probability but retaliated for some injury previously sustained at the hands of the white man.

To return from this digression, I beg to note, in passing, the great change which has occurred within the last twenty years in the appearance of the sand dunes. When settlement first took place in the West, and for years afterwards, the coast line was clothed with verdure; and west of Belfast the honeysuckle (*Banksia*) and she-oak (*Casuarina*) grew in abundance; whereas, now, the dunes are denuded of vegetation, and the trees gone, with the exception of a few very brief isolated instances; and in many cases the material of the dunes is drifting inland. In places where the action of the wind has been localised, and cut gullies in the dunes, the formations alluded to by Mr. Etheridge may be noted in abundance—namely, the filling in the cavities formerly occupied by roots of the sedge grasses, reeds, and other vegetation, with calcareous concretions, preserving the common appearance of pith and stem; but the whole is very brittle, and not in any way partaking of the character of the older formation fossils.

Between Belfast and Yambuk the dunes have in places been converted into an indurated limestone, of so firm and glassy a character that a friend one day brought me in

triumph a piece of it which he pronounced to be flint, and nothing short of an adjournment to a neighbouring chemist's would convince him to the contrary.

Inland from the coast, between four and nineteen miles from Belfast to the west, this indurated limestone is very prevalent, with the exception of an overflow of lava between the eighth and tenth miles; but how far it extends under the lava I do not know. The limestone is water-worn, is an excellent road material, and is suitable for building, and makes a strong mortar. It has many of the ingredients of an hydraulic lime, but Mr. Foord does not esteem it highly in this latter respect.

In use I found it to make the best mortar of any I have used in the colony.

Nearly the whole of the coast line from Warrnambool to Yambuk is modified by the outflow of lava from Mount Rouse, which is situated about thirty-six miles from the coast northerly.

In remote ages, when Mount Rouse was active, the whole of this region must have been one of sterile desolation over a great portion of its area, the lava stream extending over a breadth of many miles from Mount Rouse across the Hawkesdale district, and round by the high limestone cliffs of Tower Hill Marsh (an ancient coast line) to the sea, spreading out in a fan-like shape from the Sisters in Armstrong's Bay to about four miles west of Belfast.

The lines of demarcation of the lava-flow are tolerably well defined, and leave little doubt as to its source, for on the north-west, about twenty-four miles from Belfast, we have at the deep Creek the Mount Rouse lava on one side and ancient basalt on the other, which extends a considerable way north, dividing the outflow from Mount Rouse from that of Mount Napier and Mount Eccles, to which I purpose alluding presently; whilst on the east we enter on to the out-throw from Tower Hill, which is of an entirely different character to that from any of the surrounding vents, namely, those of Mount Gavoc to the east (lava), Mount Rouse to the north (lava), and Mount Napier and Mount Eccles (largely of vesicular lava); whilst Tower Hill has been wholly of ash (vesicular bluestone in a comminuted state), red-hot stone (glassy in structure), in isolated showers, dust, and vapour, which now forms the tufa of the neighbourhood.



The basalts of Mount Rouse have formed Port Fairy; whereas the indurated tufas of Tower Hill, and the indurated sand dunes of the coast, have formed Lady Bay, the lavas of Mount Gavoc having been checked in flow westward at Yangary Creek—a small stream marking the dividing line between the products of the Tower Hill eruptions and those of Mount Gavoc, which latter outflow has been further checked on the south-west by the ancient sand dunes on which Warrnambool is built. It is possible that the lavas of Mount Rouse and Mount Gavoc may blend in the country between Russell's Creek and Woolsthorpe.

To the west of Belfast, about from twenty-five to thirty miles, we come on to the outflow of lava from Mount Napier and Mount Eccles—the former having had its chief outpour through what is known as the Lowth Swamps, until it joins the Mount Eccles outflow near to Lake Condah and thence to the sea.

I have been informed that the overflow of water from Lake Condah, at one season, disappears under a portion of the basalt, and after a passage of several miles emerges again in considerable streams into Darlot's Creek, which latter empties into the sea near Portland Bay.

I may mention in this place that near to Yambuk there is one place where in flood-time a very considerable body of water enters a cavity in the indurated limestone before spoken of, and disappears, but where its exit is I never could learn.

Over nearly all the coast limestone formation there is evidence of hollows existing in the limestone, because in driving along there is the peculiar rumble as if passing over a wooden bridge or vault.

The indurated limestone has been either formed under water or submerged subsequently; but I think the evidence of formation under the sea is reliable, for I have noted what I believe to be casts of the common limpet in the rock.

I am further inclined to believe that the outflow of the lava has been at a period when the sea washed the coast line of limestone bluffs, to which I have before alluded, as forming the northern boundary of the Tower Hill marsh, and which now forms the third line inland of old sea coast. The evidence of the coast lava having been submerged to a much greater extent than at present is, I think, proven by the rounded and water-worn forms of the rock

masses—in many cases having a cup-and-ball form, which can scarcely be due to atmospheric influences alone—and the water-worn appearance of the indurated limestone between Belfast and Yambuk.

A few miles inland from Warrnambool, in the direction of Woodford, and across the River Hopkins at Allansford, in the parish of Tallangatta, there exist large formations of indurated limestone, similar in character to that described near Yambuk, at a considerable elevation above the sea, and containing abundance of marine fossil remains, indicative of formation below water.

Having thus far endeavoured to sketch in the general geological features of the district, I will now give a general view of the existing and ancient coast lines, with the evidence in favour of the views enunciated.

In the preceding notes I have pointed out the conditions which modify the line of coast as at present existent, but to those above named I must add the agency of ocean currents, which, although frequently influenced superficially by prevailing winds, all my observations have tended to confirm those made by me sixteen years ago off the coast of Gippsland as to the existence of an oceanic current from the westward, permanent in its character, and only influenced superficially by easterly and southerly weather; and it is due to the existence of such permanent current that all our harbours and rivers have an easterly or south-easterly exposure, excepting only in such exceptional circumstances as the entrance to Port Albert, in Gippsland; and this, even in its exception from the general rule, proves the law of current as stated from west to east.

From Warrnambool to Tower Hill the country consists chiefly of rounded mammaliferous hills of pulverised shell, limestone, ash, and tufa; but immediately west of Tower Hill we come upon evidences of an old inland coast line, which gradually rises into a long ridge consisting of pulverised shells, spicula, and other marine remains; amongst which, Mr. Castwood, of Belfast, has obtained sharks' teeth, from the inner or second line of ridge near to that town. Between this inland ridge and the coast exists a flat, which in part is occupied by a lagoon enclosed from the sea by the present line of sand dunes. The bed of the lagoon consists of deep alluvial deposits mixed largely with sand drift.

Inland of this second ridge, at a distance of about a mile, the land rises in steep hills, and, in some places, limestone bluffs, which extend from Tower Hill westward for from six to seven miles. The bluffs are chiefly of an indurated limestone, but the sloping hills have a thick bed of soft limestone, with abundance of shell spicula and other marine remains; and the whole has evidently been the sea-coast of what has in all probability been an indented bay, formed between the Tower Hill and the outflow of lava before described as coming from Mount Rouse.

The inclosed basin between the second line of ridge and the bluff is occupied by a bed of stiff black diluvium, through which flow the surplus waters of Tower Hill and the country to the north-east and the River Moyne, which latter rises in the marshes and stony rises south and west of Mount Rouse.

Until recently this flat was more or less a marsh during the greater portion of the year, but it has now been reclaimed by drainage.

On a portion of these flats west of the River Moyne, well shafts have been sunk to depths varying from 14 feet to 18 feet deep, and an original sea bed disclosed, with abundance of recent shells. From the River Moyne westward the land is chiefly undulating bluestone ridges, until the sea-coast or the limestone beds before described are reached.

The formation of the land and its three distinct coast lines as described indicate considerable changes of coast, and these changes must have occurred since the upheaval of the land to its present level; and so far from the line of coast being even now fixed, I have often thought when standing on the present sand dunes that I could detect in the paler colour of the sea a short distance from the present coast a new formation of coast line in progress, but the data on which I have arrived at this conclusion is not sufficiently positive to give reliable evidence of the fact; but, assuming such to be the case, the progress of formation must of necessity be slow owing to the long period requisite to accumulate fragments of shell sufficient to form these extensive mounds. The materials brought down by the river in floods can have little effect in hastening such formation, because although the outflowing current is strong enough to carry along the finer particles of mud sufficient to discolour the water, it has not velocity sufficient to convey

the more solid matters held in suspension far from the mouth of the river.

Such a formation and the agencies which I conjecture to be in operation are very similar to those of earlier times, when the second line of ridge was formed enclosing the Tower Hill marsh and the outer line which encloses the lagoon and flats between the existing dunes and the second ridge; namely, a heavy sea on the coast breaking down and carrying back with its recoil particles of the coast held in mechanical suspension across a deep water channel, until the under draft meeting with a resistance of force sufficient to check its current precipitates the solids in a long ridge, which from continuous accumulations becomes at last a shoal enclosing a basin; and in time the shoal emerges as a bank, alternately dry and wet, on which the wind can act, and then begins the process of accumulation in ridges and the filling in of the basin with vegetable deposits and growth until dry land appears.

In one place at Warrnambool the wave action from some cause has become destructive, as evinced by the erosion of the shell limestone, undermining it, and breaking down the fallen materials. The outlyers of these rocks now form dangerous reefs over which the sea breaks for about half a mile seaward of the coast line of the dunes. From what has fallen under my own observation, however, I believe the wave action along the Victorian coast is chiefly conservative, as a proof of which the long ninety-mile beach of Gippsland is an excellent example; the dunes of Gippsland bear evidence of formation from similar causes to those suggested as having been active on the western coast.

Of the long continuance of the climatic conditions existent in Victoria the out-throw from Tower Hill affords very striking evidence in the great prevalence of its products to the east and south-east of the mount, a direction which would be taken now by ejected matter in any time of great atmospheric disturbance.

The crater of Tower Hill is from five to six miles in circumference, and rises in places to 320 feet above the level of the lake, which occupies a large portion of its area, whilst the island from which it appears to have received its name rises a little higher in mounds and peaks, with one well-defined crater and the broken remains of others. When in its early times of activity, the crater must have been a yawning



gulf of the area described, and probably from 600 to 1000 feet deep; but as its activity lessened the cones of eruption formed in the interior, and these having broken out from time to time in new vents, moulded the peaks nearly as they now exist

Surrounded as Tower Hill is by extinct volcanoes, ranging at various distances from thirty to forty miles—all of which poured out molten lava in abundance—it is somewhat singular that amongst the deposits from Tower Hill there is evidence only of showers of red-hot stones, comminuted basalt, or ash-dust and vapour. The stones are glassy in fracture, and are obtained in the sides of the crater and adjacent pastures; but the ash and the dust and vapour which form the tufa extend around for several miles' distance, but more especially to the south and east in the direction of Warrnambool, precisely as if ejected under existing meteorological conditions. It is to the vast volumes of steam ejected, and the heavy rainfalls which would accompany these great atmospheric disturbances concomitant with violent eruptions, that I attribute the induration of the sand dunes on which Warrnambool is built into strata of rock bending equably over in the form of mammaliferous hills; and as each layer or bed of sand became blown over and covered the former layer, fresh precipitation of moisture would dissolve, and the solution would penetrate and cement the loose particles of shell together; and so the process would continue for such time as Tower Hill continued to eject matter.

Evidence of the formation of these dunes on dry land is occasionally given by the exposure of the imprint of footmarks of some three-toed animal or bird, which may have been either emu or kangaroo, the impressions being sufficiently distinct as a footprint, walking on sloping ground, but scarcely so clear an impression as to indicate precisely the nature of the animal.

On the flank of Tower Hill, near Yangery, a shaft was sunk through the layers of ashes and tufa to a depth of from 70 to 80 feet and a bed of ancient turf exposed; but this depth I believe to be a minimum.

From a careful consideration of all the preceding facts, and from reasoning based on them, I have been able to arrive at only one conclusion, namely, that between Warrnambool and Yambuk the form of coast line has been determined by the outflow of molten lava; that three coast

lines have been formed in succession between Tower Hill and Belfast, and that in all probability there is now a fourth in course of formation; whilst at Warrnambool the outliers of rock are but the original dunes partially dissolved and cemented together by the volumes of vapour and of rain either ejected from or induced by the action of Tower Hill in remote times; and lastly, from the vast preponderance of Tower Hill out-throws existing in greater quantity and to a much greater distance in an easterly and southeasterly than in any other direction, that meteorological conditions under circumstances of great atmospheric disturbance were in remote times the same as at present—and if in times of great disturbance of which we have evidence, then also in periods of comparative repose, and hence climatic conditions over very remote periods were the same as now.

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ART. VII.—*Notes on the Recent Earthquake.*

By R. L. J. ELLERY, ESQ., F.R.S., F.R.A.S.

[Read 12th July, 1877.]